

Shear Production And Dissipation In A Stratified Tidal Flow

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LONG-TERM GOALS

The long term goal of this work is to understand the physics of turbulent stratified shear flows as might be found in coastal regions and estuaries where both shear and stratification are strong. It is our hypothesis that turbulence under these conditions of active generation may function in a way that is fundamentally different from weak turbulence below the thermocline (or above the bottom mixed layer) in the ocean. We anticipate that such an understanding will permit the development of accurate predictive models of turbulence dynamics for energetic coastal flows.

OBJECTIVES

This project, carried out in conjunction with Mike Gregg of the Applied Physics Laboratory at the University of Washington, has as its objective obtaining a relatively complete set of observations of turbulence structure and variability in Suisun Cut, a tidal channel in Northern San Francisco Bay. In this region both tides and stratification are strong: typical shears might be 0.1 s^{-1} with comparable buoyancy frequencies. These conditions typify coastal zone flows. Given these conditions, flows in Suisun Cut are found to have high turbulence Reynolds number over a wide range of flow stabilities. Past work, reported in Stacey et al 1999, using an Acoustic Doppler Current Profiler (ADCP) to measure turbulent Reynolds stresses however assumed that the rate of shear production of turbulent kinetic energy was in balance with turbulence dissipation. The new work will build on the Stacey et al. results by including direct measurements of profiles of turbulence dissipation rates (Gregg) and bottom stresses using Acoustic Doppler Velocimeter (ADV - Monismith/Burau) to water column ADCP derived turbulence measurements (Monismith/Burau). Moreover, the data reported in Stacey et al represented the evolution of the flow over 1 tidal day during a neap tide; in the new work, we plan up to 2 weeks of observations spanning a complete neap-spring tidal cycle. Thus, we expect to obtain a substantially more comprehensive picture of flow behavior than was previously available.

Besides improving our empirical description of these stratified shear flows, we also plan to use this data set in conjunction with Large Eddy Simulation (LES) studies of stratified turbulence to develop new (and improved) models of stratified turbulence behavior.

APPROACH

A field experiment involving synoptic measurements of turbulence dissipation (via dissipation profilers), turbulent Reynolds stresses and production (ADCPs and ADVs), density structure (via autonomous CTDs), and sediment re-suspension (using calibrated Optical Backscatter Sensors - OBS) was carried out between the 14th and 27th of October 1999 in Suisun Cutoff in Northern San Francisco Bay. Fixed instruments were deployed by the Stanford/USGS group in the center of the channel where between the 18th and 26th of October Mike Gregg's group carried out extensive dissipation profiling and acoustic imaging. Specifics of Gregg's measurement program will be discussed in his report.

The Stanford /USGS group used/deployed the following fixed instruments:

1. A bottom frame carrying 3 ADVs (distributed over the bottom 1m of the water column), 3 OBS (coincident with the ADV measurement volumes), 1 conductivity/temperature (CT) sensor pair, a pressure transducer, and an inclinometer. The OBS, CT and pressure sensors were connected to a single Ocean Sensors OS200 CTD. Along with the CTD, all 3 ADVs, were cabled to the surface and connected to data logging computers kept on a houseboat that was anchored nearby. Matt Brennan, a PhD student of the PI has responsibility for this data.
2. A pair of ADCPs mounted on a single frame with one ADCP looking up and one looking down were deployed to record shear stresses and turbulent kinetic energy (TKE) profiles over the entire water column. The downward looking unit was a 600 KHz workhorse unit set to sample 10cm bins in RDI's pulse-to-pulse coherent mode, mode 5. The upwards looking 1200 KHz ADCP sampled 0.25 m bins using RDI's broadband mode, mode 4 (as in Stacey et al 1999). Both ADCPs were cabled to computers on the houseboat for logging of every ping. Prof. Mark Stacey of U.C. Berkeley has taken responsibility for acquisition and initial processing of this data.
3. An ADCP (1200 KHz, mode 4, 0.25m bins) and an autonomous CTD (set to profile every 10 minutes), both mounted on the houseboat were used to measure density, sediment, velocity and stress/tke profiles over the upper 85% of the water column. Matt Brennan and the PI will be responsible for this data.
4. Two autonomous CTD profilers were deployed at either end of the 3km long channel to measure density profiles and hence the baroclinic pressure gradient in the cut. Additionally, two Seabird seagauge pressure recorders were also deployed at either end of the channel to record the barotropic tidal pressure gradient. Burau and Monismith will be responsible for this data.

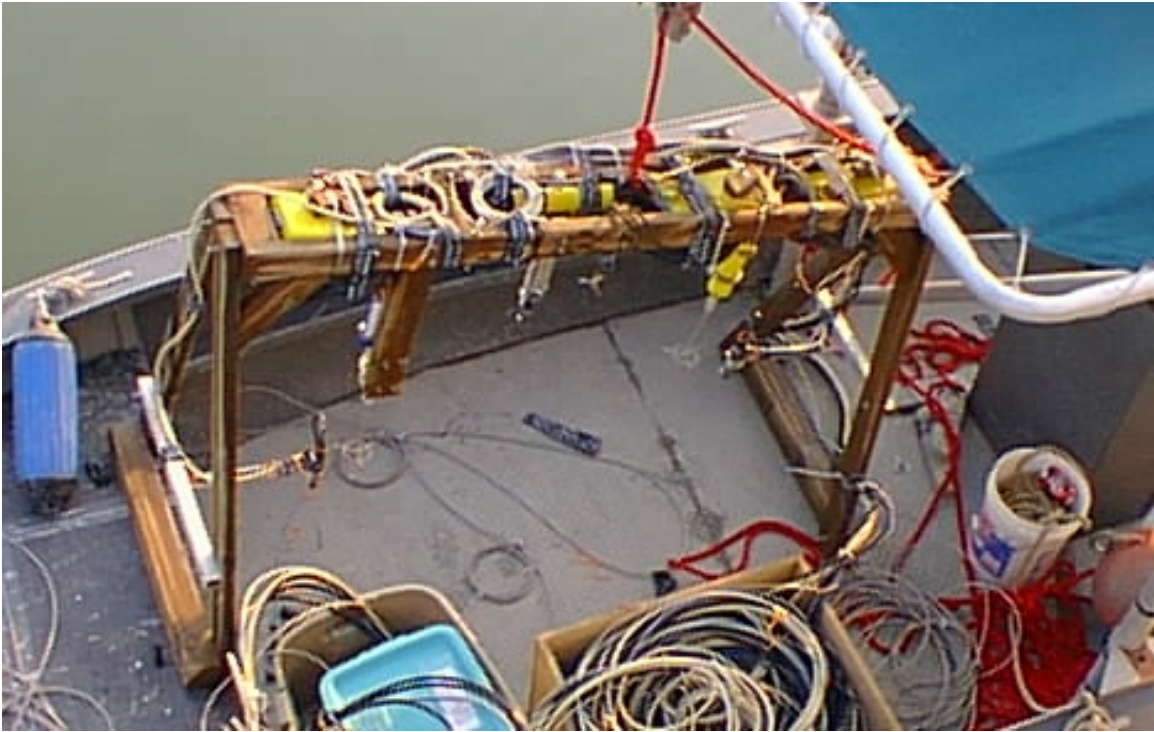


Figure 1: ADV frame prior to redeployment October 17, 1999. In addition to 3 ADVs, 3 OBS sensors (on their supports) can also be seen in this picture. The ADV processing units sit in the top of the frame, which was aligned so that the principal tidal currents passed between the legs.

In addition to these fixed deployments, as part of its own Bay research program, the USGS also made several month-long deployments in the larger Suisun Bay region of several ADCP and top-bottom salinity recorders. This data will provide background hydrographic data for interpretation of data taken during the intensive turbulence field experiment. Finally, also as part of a separate project (supported by the state and federal agency Cal-Fed Bay Delta Program), on two days, October 20 and October 26, extensive ADCP/CTD transects were taken in Suisun Cutoff for about 15 hours on each day.

All of the ADCP and CTD data acquired will be processed using the methods described in Stacey et al (1999) to produce (initially) fields of velocity, density, Richardson number, stress, TKE, production (for comparison to dissipation measurements), turbulence length scale (for comparison to overturning scale measurements by Gregg's group), turbulence Froude number, and the activity parameter defined using the dissipation rate, ϵ , i.e., $\epsilon/\nu N^2$. We expect this data set to give a detailed and comprehensive picture of how stratified turbulence behaves for a wide range of shear and stratification conditions.

WORK COMPLETED

All of the deployments discussed above were carried out and, at the time of writing, all of the fixed turbulence instruments have now been recovered (on the 27th). During this time most of the instruments were functional, although one of the ADVs stopped communicating after redeployment of the frame on the 19th, and the OS200 CTD was inexplicably disfunctional for several days around the 22nd. It is planned that the pressure gauges will be left in until early November or so to provide a reasonable record for harmonic analysis.

RESULTS

All data is currently in raw form - results will be available after first-cut analysis of data is completed in the spring

IMPACT/APPLICATIONS

We expect that this data set will be useful in future for developing and testing turbulence models for coastal zone applications.

TRANSITIONS

This data will be made freely available, probably via web access, to other groups working on stratified turbulence.

RELATED PROJECTS

A STUDY OF THE STRUCTURE OF NEAR COASTAL ZONE WATER COLUMN USING NUMERICAL SIMULATION (ONR - Koseff, Ferziger and Monismith) - This work is using Large Eddy Simulation to study the physics of flow influenced by stratification and by surface waves.

CHARACTERIZATION AND MODELING OF PLUMES AND ANIMAL PLUME-TRACING IN WAVE-INFLUENCED COASTAL ENVIRONMENTS (ONR - Koseff and Monismith) - The portion of this work for which Monismith is responsible involves field experiments looking at plume dispersion and plume source in the near-shore environment. These experiments are part of the ONR Chemical Sensing in the Marine Environment Program managed by Dr. Keith Ward.

REFERENCES

Stacey, M.T., S.G. Monismith, and J.R. Burau (1999), "Observations of turbulence in a partially stratified estuary," J. Phys. Ocean. 29 pp, 1950 - 1970.